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A COMPARISON OF THREE FLOODING REGIMES
ATCHAFALAYA BASIN, LOUISIANA

by

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FOREWORD

Protection of the environment requires effective regulatory actions which are based on sound technical and scientific information. This information must include the quantitative description and linking of pollutant sources, transport mechanisms, interactions, and resulting effects on man and his environment. Because of the complexities involved, assessment of specific pollutants in the environment requires a total systems approach which transcends the media of air, water, and land. The Environmental Monitoring and Support Laboratory-Las Vegas contributes to the formation and enhancement of a sound monitoring data base for exposure assessment through programs designed to:

- develop and optimize systems and strategies for monitoring pollutants and their impact on the environment
- demonstrate new monitoring systems and technologies by applying them to fulfill special monitoring needs of the Agency's operating programs

This report compares hydrologic regimes of three backwater areas in the Atchafalaya Basin, Louisiana. The purpose of these comparisons is to improve the understanding of process-environment relationships as a basis for evaluating management alternatives regarding protection and enhancement of the Basin's environmental quality and related resource values, including flood control. The U.S. Environmental Protection Agency, the U.S. Corps of Engineers, the U.S. Department of Interior, the State of Louisiana, special interest groups, and other interested individuals will use this information to assess the potential impact of the hydrological modifications proposed by the Corps. The information will also be useful to those who develop alternative land and water-quality management plans which will accommodate flood flows and maintain an acceptable level of environmental quality. Further information on this survey may be obtained from the Water and Land Quality Branch, Monitoring Operations Division.

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ABSTRACT

Three backwater areas in the Atchafalaya Basin, Louisiana, are compared. The purpose of this comparison is to improve the understanding of process-environment relationships as a basis for evaluating management alternatives regarding protection and enhancement of the Basin's environmental quality and related resource values and the use of the Basin for flood control. The three areas studied are Fordoche and Buffalo Cove, within the Atchafalaya Basin Floodway and subject to annual flooding by the Atchafalaya River, and Pat Bay which is located outside the floodway and in which flooding is controlled by local rainfall. Hydrologic regimes are compared for relative contributions of river water and local drainage, amplitude of water level fluctuations, mode of water introduction and movement, and related introduction of sediments. From the comparison, the following were seen as the most urgent needs for management of Atchafalaya Basin Floodway units: 1) induction of low discharge throughflow in order to enhance water exchange in those areas presently subject to a backwater regime and insufficiently dewatered, 2) reduction of inflow associated with short term water level fluctuations during the annual rise of Atchafalaya River stages in order to reduce sediment introduction, 3) maximum utilization of the unit's precipitation surpluses as a source of floodwater to reduce inflow of Atchafalaya River water and sediments, 4) realization of 1), 2), and 3) through water introduction at the upper end of the unit and simultaneous control over outflow at the lower end of the unit.

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LIST OF SYMBOLS AND ABBREVIATIONS

EPA - U.S. Environmental Protection Agency

U.S.C.E. or USCE - U.S. Corps of Engineers

MSL or msl - mean sea level

m - meters

m/s- meters per second

kg/s - kilograms per second

lbs/s - pounds per second

g/l - grams per liter

km - kilometer

cfs or c.f.s - cubic feet per second

cms or c.m.s. - cubic meters per second

mos. - months

ACKNOWLEDGMENTS

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Several members of the Coastal Environments, Inc., staff contributed to specific elements of this study. We wish to acknowledge in particular the contributions of Mr. Philip Light and Dr. Sherwood M. Gagliano, the cartographic work of Curtis Latiolais and editing of Peggy King and Ava L. Haymon.

SECTION I

INTRODUCTION

The Atchafalaya Basin in south-central Louisiana is a large [4,500 square kilometers (km^2)] alluvial basin that has national significance as a multiple resource. It derives this significance principally from high quality habitats for fish and wildlife, a semi-wilderness area of high recreational value, and its function as a floodway for the lower Mississippi River.

The quality and long-term use of these principal resources are increasingly endangered because present land and water uses are in conflict with hydrologic requirements of the natural environment as well as among themselves. These conflicts have dictated the need for development and implementation of an effective multi-use land and water management plan to sustain or enhance environmental quality and to achieve modes of use that recognize environmental constraints.

As part of an interagency study by the U.S. Corps of Engineers (U.S.C.E.), the U.S. Environmental Protection Agency (EPA), and the U.S. Fish and Wildlife Service, two successive studies focused on the need for the requirements of surface water management. The first Environmental Protection Agency study dealt with identification of the Basin's environments and the manner in which their aggregate characteristics are controlled and affected by natural processes and human use (Gagliano and van Beek, 1975). This work defined major problems and developed conceptual guidelines for surface water management. The second study report is a continuation of the first, with more detailed consideration of water needs of the natural environment and of the various land and water uses. On the basis of general water management requirements for the Atchafalaya Basin as a whole and specific requirements for its primary use as a floodway, a multi-use management plan was developed (van Beek _et al_., 1976) and presented as an alternative to channelization as proposed by the U.S.C.E.

The previous studies showed clearly that acceptance of flood control as the primary management objective is not incompatible with the need to protect and enhance the natural environment. On the contrary, the two have a parallel major requirement in that both flood control and natural resource values of the Atchafalaya Basin need be managed so that neither is adversely affected. This holds not only for the present floodway, but also for areas outside the floodway which may be required when capacity of the present system is further reduced.

Within the present floodway, the essential management requirement for both flood control and environmental quality is to reduce sedimentation associated with annual introduction of Atchafalaya River water. At present, sedimentation in backwater areas is the main threat to an already reduced and insufficient floodway capacity and to the overflow areas as fish, wildlife, and swamp forest habitats. Management strategies should, therefore, be aimed at annual introduction of Atchafalaya River water into the swamp basins only to the extent necessary to meet hydroperiod, water level, and water quality requirements. Furthermore, introduction of water should occur in such a way that associated sediment influx is minimal and that unavoidable sedimentation is least detrimental to the natural environment and floodway capacity.

Development of detailed management strategies for the floodway swamp have become most urgent in view of pending plans for further channelization of the Atchafalaya River. As authorized, the channelization project is intended to reduce sediment influx into backwater areas through a reduction in normal-year river stages so that less water is diverted into overbank storage. First, this conflicts severely with water needs of the overflow swamps. Second, the authorized project does not alter the mode of water diversion, which is believed to be the main cause of the present excessive and detrimental sedimentation.

An alternative approach to water management for flood control, more compatible with environmental quality needs, was developed in the previous studies (Gagliano and van Beek, 1975; van Beek _et al_., 1976). That approach suggests: 1) confinement of Atchafalaya River flows to enhance enlargement of the Main Channel through natural processes, and 2) structural management of water diversion from the river into the backswamps so that control can be exerted over volume, quality, and inflow process.

General recommendations were made concerning control over diversion from the Main Channel and desirable stage variation. However, insufficient information was available to make recommendations concerning the various possible modes of water introduction into individual swamp sub-basins or management units. Therefore, the present study was undertaken to compare the hydrologic regime of three sub-basins that differ from each other with regard to mode of flooding, stage variation, relative contribution of Atchafalaya River water and local runoff, and type of environment. The sub-basins selected were Fordoche, Buffalo Cove, and Pat Bay (Figure 1-1). In addition to showing necessary hydrologic variation, those areas were chosen because they formed distinct hydrologic units with well-defined boundaries and points of water exchange. The above three areas were also chosen because baseline studies concerning biota and water quality (Lantz, 1974; Bryan _et al_., 1974) and management requirements (Gagliano and van Beek, 1975; van Beek _et al_., 1974; van Beek _et al_., 1976) are available. Baseline data were also available from the U.S. EPA and the U.S. Fish and Wildlife Service ongoing studies.

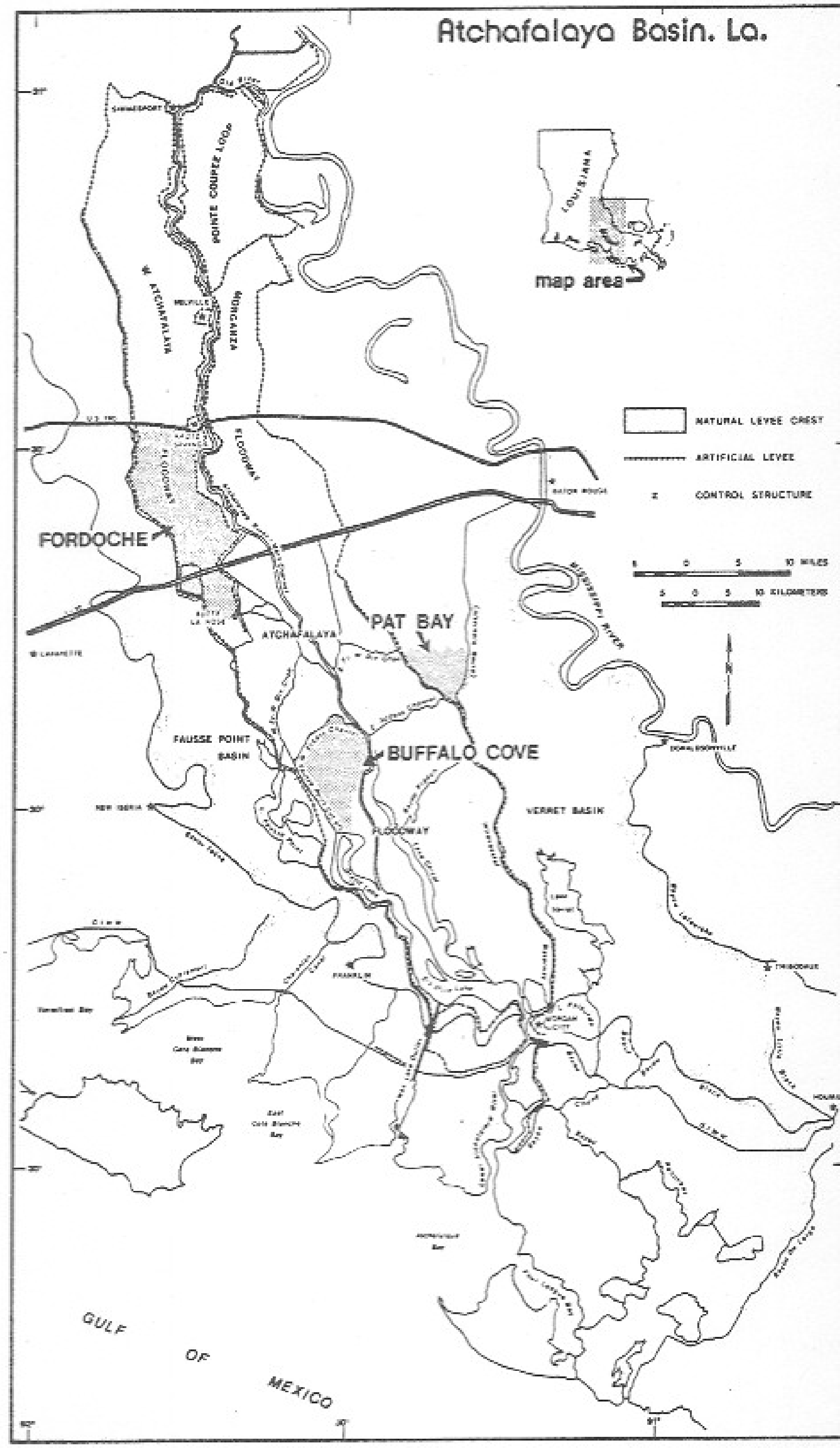

Figure 1-1. Location of three study areas within the Atchafalaya Basin.

SECTION II

CONCLUSIONS

1) Fordoche and Buffalo Cove differ from Pat Bay primarily because of greater amplitude of annual stage fluctuation and partly because of contribution of Atchafalaya River water to annual flooding.

2) Both Buffalo Cove and Pat Bay experience primarily a backwater flooding regime with throughflow limited mostly to the lower margin and involving the lake environment.

3) In Fordoche, introduction of external, local drainage produces a throughflow regime during most of the year throughout the unit, but backwater flooding does occur in the lower half of the unit during Atchafalaya River flood stages.

4) The relative contribution of Atchafalaya River water to annual flooding during the 1975-1976 study period was five times as great in Buffalo Cove as in Fordoche.

5) The relative contribution of precipitation surpluses to annual flooding was approximately three times as large in Pat Bay as it was in Fordoche and Buffalo Cove.

6) In Pat Bay short-term fluctuations of water level exceed average annual fluctuation in amplitude.

7) On a comparable basis, water replacement in Pat Bay about equaled that of Fordoche and was nearly one and a half times greater than in Buffalo Cove.

8) Short-term fluctuations during the annual rise of river stage increased sediment input into Buffalo Cove by a least 20 percent.

9) In Fordoche, short-term inflows were eliminated by the throughflow regime but related reduction in sediment input was more than offset by the sediment input associated with inflow of drainage through the Courtableau Drainage structure.

10) Buffalo Cove experiences high sedimentation rates because a single major channel introduces most of the water to a small portion of the area experiencing an unimpeded throughflow regime.

11) To minimize sediment introduction into floodway units requires reduction of short-term stage fluctuations and maximum use of precipitation surpluses. This can be obtained without adversely affecting water exchange only by management for a throughflow regime in which discharge rates are no higher than the minimum necessary to maintain required circulation.

12) With the constraints of the Atchafalaya Basin Floodway, a managed throughflow regime is more likely to enhance environmental quality than a backwater regime.

SECTION III

RECOMMENDATIONS

1) Water management should provide for maximum use of local precipitation surpluses to reduce the need for introduction of sediment-laden river water into floodway swamp environments.

2) Except when necessary to maintain environmental quality, short-term water level fluctuations in floodway swamp basins should be reduced in order to reduce river water introduction while maintaining desired extent, depth, and duration of annual flooding.

3) Data collection and analysis concerning the hydrologic regimes of at least Fordoche, Buffalo Cove, and Pat Bay should continue in order to include conditions other than the 1975-1976 water year, during which Atchafalaya River stages were below average.

4) Hydrologic regime characteristics should be related to biological parameters other than vegetation associations and to water quality parameters to provide a more complete basis for management decisions.

5) Pending verification of present findings through inclusion of normal-year hydrologic data, it is recommended that a water management plan for the floodway swamp provide for a throughflow regime in which, at least during flood stages, water is introduced at the upper end of each basin through overbank flow when possible and in which outflow is controlled to maximize use of precipitation surpluses and to control the rates of inflow and throughflow.

SECTION IV

GENERAL CHARACTERISTICS OF STUDY AREA AND SCOPE OF STUDY

Historically, the Atchafalaya Basin contained a complex of lakes and backswamps which were interspersed with and surrounded by natural levee ridges of varying magnitude. Bald cypress and tupelo gum predominated in the swamps, while mesophytes grew on the higher ridges and natural levees. Early accounts of oak lumbering in the area (Comeaux, 1972) indicate that oak was probably an important component of these mesic associations. The swamps were subject to an annual flooding and dewatering regime of moderate amplitude that was governed by local rainfall and limited introduction of Mississippi River and Red River waters.

The above setting rapidly changed over the past 75 years. Lumbering, farming, increased Mississippi River diversion and an associated increase in sedimentation, floodway construction, and channelization drastically altered the hydrologic regime, topography, and natural vegetation patterns. New controls were instituted on hydrologic and sedimentary processes and on the distribution and predominance of particular vegetation associations (van Beek et al., 1976; O'Neil et al., 1975). As a result, the three areas selected for study differ significantly with regard to environmental composition. They reflect modification of the natural environment caused by a combination of human and natural processes.

The most obvious difference is between Pat Bay, on the one hand, and Fordoche and Buffalo Cove on the other. Construction of the Atchafalaya Basin Floodway separated the basin into a central area dominated by riverine processes and two marginal areas where in situ processes prevail (Gagliano and van Beek, 1975). The Pat Bay study area lies outside the floodway in the eastern marginal area, or the Verret Basin; the Fordoche and Buffalo Cove sub-basins are located within the floodway (Figure 1-1). The Buffalo Cove and Fordoche units show differentiation due to progressive southward building of the Atchafalaya River floodplain. The Fordoche area, located further north, has been subject to riverine processes for a longer period of time. Therefore, succession toward a terrestrial environment is more advanced. These differences will be expanded upon in the following chapters through analysis of the three sub-basin environments as they relate to present and past natural processes and human use.

Emphasis in the present study is on the analysis and comparison of hydrologic regimes of the three units with regard to annual introduction of river water, annual introduction of sediment, and habitat differentiation. Associated with each of the above aspects is a large number of pertinent questions that will require at least partial answers prior to implementation of an overall management plan. One of these questions concerns the mode and volume of water introduction into individual swamp basins, which determine the pattern and amount of backwater sedimentation.

Sediment is carried into backwater areas by Atchafalaya River water diverted from the Main Channel. Therefore, to reduce detrimental effects of sedimentation, there are three basic options. The first is to reduce the volume of water diverted into the backwater areas. The second is to reduce the concentration of sediments carried by the diverted water. The third is to manage the flooding processes in such a way that sediment is deposited where it least affects valuable aquatic habitats.

Reduction of water diversion into backwater areas can be accomplished in various ways. One is to alter the hydrologic regime by means of the proposed channelization of the Main Channel. Since this leads to substantial decreases in the duration and extent of annual flooding, this method is inconsistent with the need to maintain and enhance renewable resource value and environmental quality as part of improved floodway use.

Reduction of water diversion is also possible without decreasing the extent and depth of flooding. Two possibilities are to reduce the flux of river water and to capitalize on local runoff as a partial substitute for river water. In various areas, such as the southern part of the Buffalo Cove Management Unit, river water moves through the unit at nearly all times. Inflow and outflow occur simultaneously with only different proportions determining whether stages are rising or falling. This type of condition may be referred to as a throughflow regime and is illustrated in Figure 4-1C. In such a case, inflow exceeds the volume of water required to equalize stages on the inside and outside of the swamp basin.

A throughflow regime is conducive to excess sedimentation and rapid loss of aquatic habitat, particularly when water introduction through overbank flow is eliminated as a result of the artificially increased height of surrounding levee ridges (Figure 4-1D). In such a case, the entire inflow is confined to a usually small number of channels, with a resultant increase of inflow velocities. These high velocities allow, in turn, for high concentrations of sediment in the inflowing water; this concentration of sediment is sustained until inflowing waters enter a lake or swamp environment where the water is no longer confined. There, sediment is deposited and causes a rapid environmental transition, with loss of high-quality aquatic habitat. Furthermore, it is evident that introduction of sediment under the throughflow regime increases with the rate of flux.

Contrasting with the above flooding process is the backwater regime. As illustrated in Figure 4-1A, water other than precipitation is introduced into the swamp basin only across the lower boundary of the basin and only to the extent that such becomes necessary to equalize water levels on the inside and outside. Water thus moves in and out of the basin rather than through it. With regard to river water introduction, the Fordoche area may be considered a backwater area. However, the backwater regime is modified because of

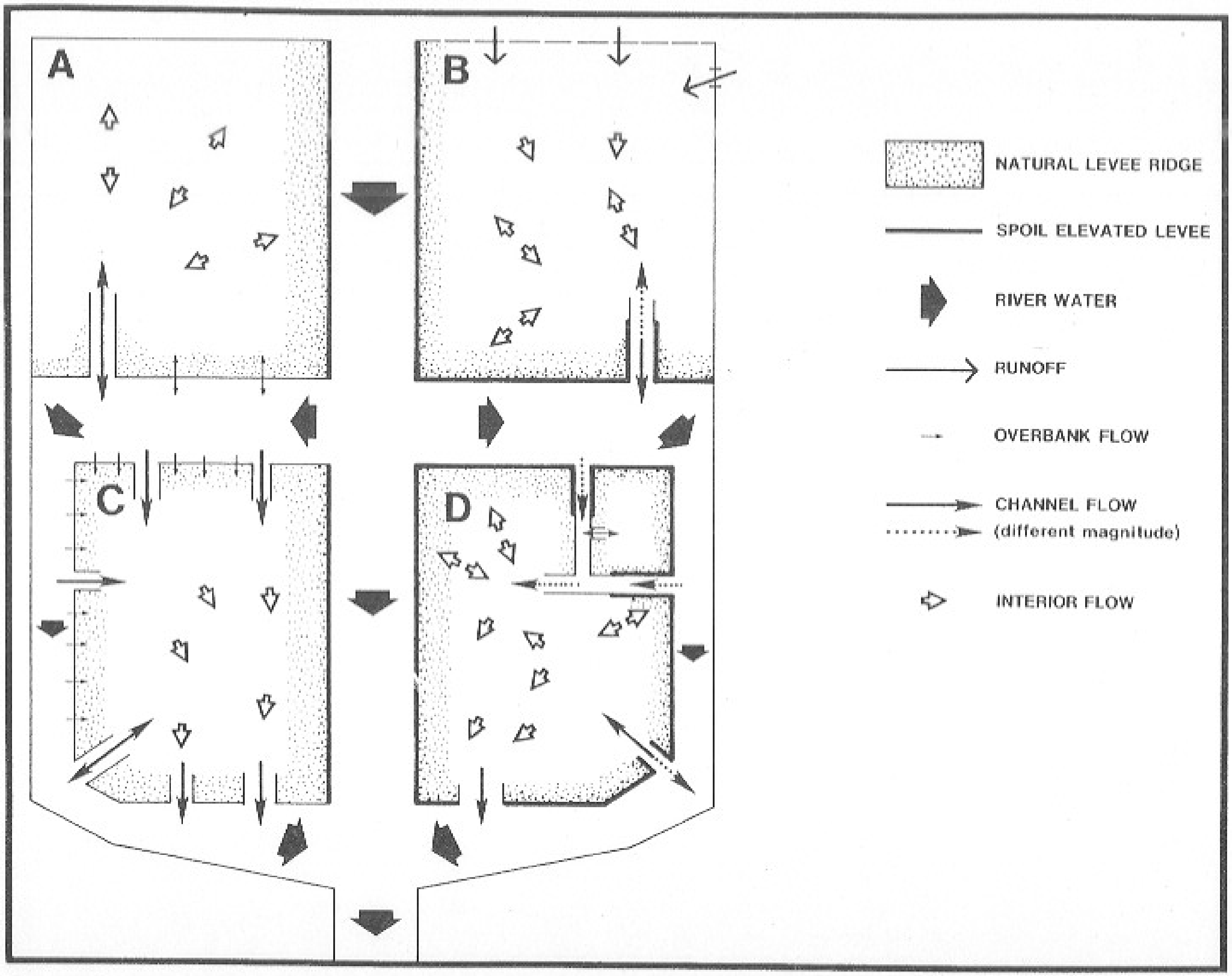

Figure 4-1. Various modes of water introduction into individual swamp basins. A. Backwater flow; B. Modified backwater flow; C. Throughflow; D. Modified throughflow.

introduction of runoff into the Fordoche basin from outside the floodway. Obviously, inflow of river water to only the extent necessary to equalize flow also reduces the introduction of excessive sediment.

Water needs and sedimentation can be further reduced when flooding and dewatering of the swamp basins are managed in such a way that a gradual rise and recession occurs without the many fluctuations. Every fluctuation means an inflow of water and sediment that contributes only partially or not at all to the necessary annual flooding and dewatering. In other words, reduction of inflow may be obtained by limiting it to those volumes necessary to produce a desired stage rise and to maintain circulation.

Necessary structural controls would also allow maximum use of precipitation surplus by holding such a surplus during times when a water level rise is desired, even though river levels may be temporarily falling. Runoff stored in this way would decrease the volume of river water needed to meet given water level requirements.

Whereas the previous discussions contrast backwater flow and throughflow, a second differentiation as to mode of flooding can be made; that is, between overbank flow and channel flow. It was pointed out already that elimination of overbank flow increases inflow velocities and thereby sediment concentrations of the inflowing water. Channelized inflow causes sediment to be carried toward the center of the swamp basin, where it eliminates aquatic habitat. In fact, continuation of such a sedimentation pattern will eliminate a swamp basin as a depression because elevations of the interior area will eventually equal that of the rim. In contrast, introduction of water into a swamp basin through overbank flooding should change the pattern of sedimentation and greatly minimize its detrimental effect. Most sediment would be deposited along the basin rim where inflow velocities are reduced as water moves through the vegetation that occupies the rim. This is the natural process by which the basin-levee complex developed in the first place and by which this type of environment is usually sustained.

Whether the above possibilities are acceptable alternatives depends on a number of factors related to environmental quality and biological productivity. At present, it is not yet possible to estimate, for example, the extent to which river water can be substituted for by local runoff or the number of stage fluctuations reduced without adversely affecting environmental quality and biological productivity. Yet, the necessity of acquiring that type of information is apparent and is, in part, why the present study was undertaken. By comparing the hydrologic regimes of three areas that differ with regard to contributions of river water to annual flooding, amplitude of stage fluctuations, mode of water introduction, apparent sedimentation, and other related aspects, at least a basis can be established for evaluating management alternatives.

An equally important complex of questions concerns the relationship between hydrologic regimes and habitat. Development of water management guidelines requires more than an understanding of hydrologic functioning of various swamp basins. Other hydrologic aspects that enter into the decision-making process concern the duration and depth of flooding and sediment introduction, as these determine the type and distribution of biological communities.

The present study, in comparing hydrologic regimes and environments of the aforementioned swamp basins, builds further on approaches and data developed during the previous water management studies of the Atchafalaya Basin. In addition, a field program was conducted over the period of September 1975 through June 1976. Discharges were measured monthly, on the average, at all inlet and outlet channels of each of the three swamp basins. Simultaneously, depth-integrated samples of suspended load were obtained. The samples were analyzed in the laboratory for concentrations of sand and silt plus clay fractions. Staff gages were placed in the center of each of the three study areas to augment daily stage observation at U.S.C.E water level gages. Measurements and sampling proceeded according to the guidelines established by the U.S. Geological Survey (Guy and Norman, 1970). With regard to habitat differentiation and interior circulation, field surveys included qualitative observations and incidental measurements during traverses through each of the swamp basins. Field surveys served furthermore to augment information derived from aerial photo interpretation.

The following three chapters will analyze separately the three study areas, Fordoche, Buffalo Cove, and Pat Bay.

SECTION V

BAYOU FORDOCHE

This section of the report will discuss the Bayou Fordoche study area, a distinctly bounded area between the outer floodway levees and the Atchafalaya River guide levees. The boundaries and setting will be discussed first. Then the hydrologic regime will be discussed, under "Annual flooding," followed by the vegetation and wildlife, under "Habitat." In "Water and Sediment Budget, 1975-1976," the rates of sedimentation in the Fordoche area are analyzed in terms of the sources and stages of water introduction there.

BOUNDARIES AND SETTING

The Bayou Fordoche area covers approximately 270 km^2 of the Atchafalaya Basin floodway immediately south of U.S. Highway 190 (Figure 1-1 and 5-1). Rigid boundaries delineate the area as a hydrologic unit. The western boundary is formed by the continuous artificial levee of the floodway; the eastern boundary by the continuous artificial levee of the Atchafalaya River. U.S. Highway 190 and railroad embankments form the northern boundary, and a natural levee ridge associated with an abandoned Teche distributary bounds the area to the south.

Topography reflects the area's geologic history as an inter-levee basin between the Teche and Atchafalaya River natural levees. A broad, natural levee ridge which extends along the eastern margin is related to former annual overflow of the Atchafalaya River. Similar natural levee ridges parallel Bayou Courtableau, extending northwestward into the northern half of the area. These are reminiscent of the time that Bayou Courtableau served both natural drainage into and diversion of water and sediment from the Atchafalaya River. The levee ridges form the highest ground and are occupied mainly by bottomland hardwoods.

The western half of the area is occupied by a depression extending north-south over the entire length of the area. The northern two-thirds of this depression is covered with swamp and bottomland hardwood forests, while the southern one-third contains Henderson Lake.

Related to the above setting, drainage is westward from the Atchafalaya natural levee ridge into the depression and southward through the depression into Henderson Lake. Bayou Fordoche serves as the primary drainage stream for the depression with numerous smaller bayous contributing.

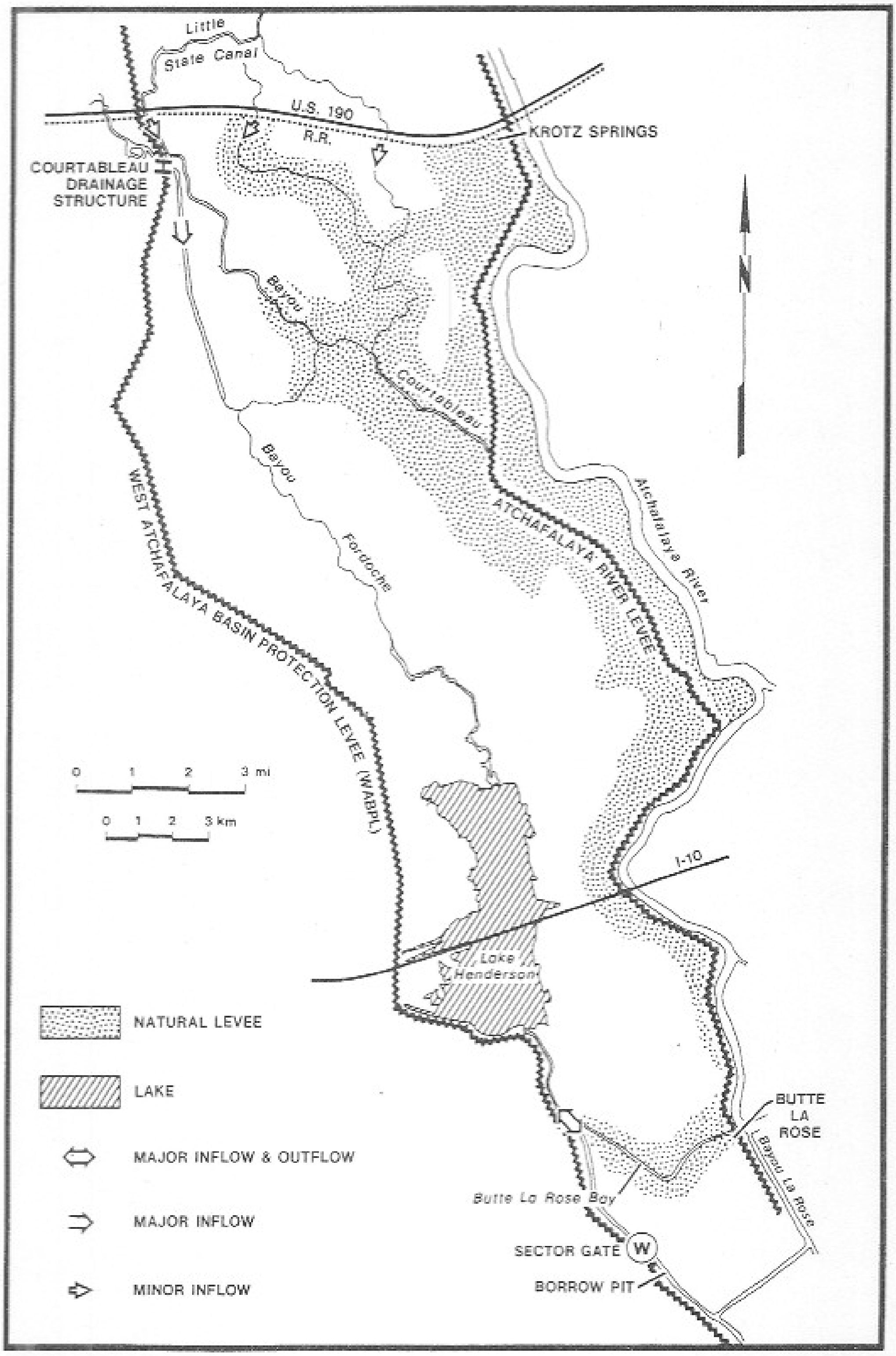

Figure 5-1. Geomorphic characteristics and inflow locations, Fordoche Management Unit.

ANNUAL FLOODING

Two sources of water, the Atchafalaya River and local runoff, contribute to annual flooding, but the rigid boundaries of the Fordoche unit place distinct constraints on routes of water introduction. Atchafalaya River water enters across only the southern boundary through the West Atchafalaya Basin Protection Levee borrow pit after diversion from the river into Bayou La Rose (Figure 5-1). Introduction of local runoff from outside the Fordoche unit can occur across the northern boundary and through the Bayou Courtableau Drainage Structure located in the West Atchafalaya Basin Protection Levee. Little State Canal and two smaller channels allow drainage water from the West Atchafalaya Floodway to the north to enter Fordoche.

Dewatering of the Fordoche area occurs almost entirely through the West Atchafalaya Basin Protection Levee borrow pit and is equally dependent on Atchafalaya River stages at Butte La Rose. However, dewatering can be controlled below 2.25 m above mean sea level (MSL) because of a sector gate built for that purpose in the borrow pit (Figure 5-1).

Average conditions for the annual flooding regime are depicted by Figure 5-2 in the form of two mean annual hydrographs and three elevation frequency or hypsometric curves. Hydrographs give average monthly stages as recorded over the period 1961 through 1970 in the northern half (Bayou Fordoche) and the southern part (Henderson Lake). Hypsometric curves give the percentage of area below a given elevation or water level along U.S. Corps of Engineers (USCE) survey ranges characteristic for the northern part (Range 1), central part (Range 6), and southern part (Range 8), of the Fordoche unit, respectively. Range locations and gage locations are shown later in Figure 5-5.

The northern part is defined as the area between U.S. Highway 90 and range line 5. The central part extends from range line 5 southward to range line 7, and the southern part occupies the remaining area south of range line 7. Elevation distributions along Ranges 1, 6, and 8 are taken as representative of the above three areas respectively.

Water levels are highest in April/May and lowest in September, October, and November. Maximum levels are about equal in the upper and lower parts of the unit, but levels differ by about 1.2 m during low stage. Thus, a southward gradient is present during most of the year which maintains water movement from north to south. Also, stage variation is twice as large in the southern part (Henderson Lake, 2.7 m) as in the northern part (Bayou Fordoche, 1.3 m).

Comparison of the hypsometric curves and hydrographs in Figure 5-2 reveals a gradient in depths and duration of annual flooding from north to south. The Bayou Fordoche hydrograph applies to northern Fordoche (Range 1), while the Henderson Lake hydrograph, because of the lesser open water gradient, approximates levels in both central (Range 6) and southern (Range 8) Fordoche. The graph, then, shows that during high stage, only 50 percent of the northern third of the unit is flooded while about 80 percent of the central and

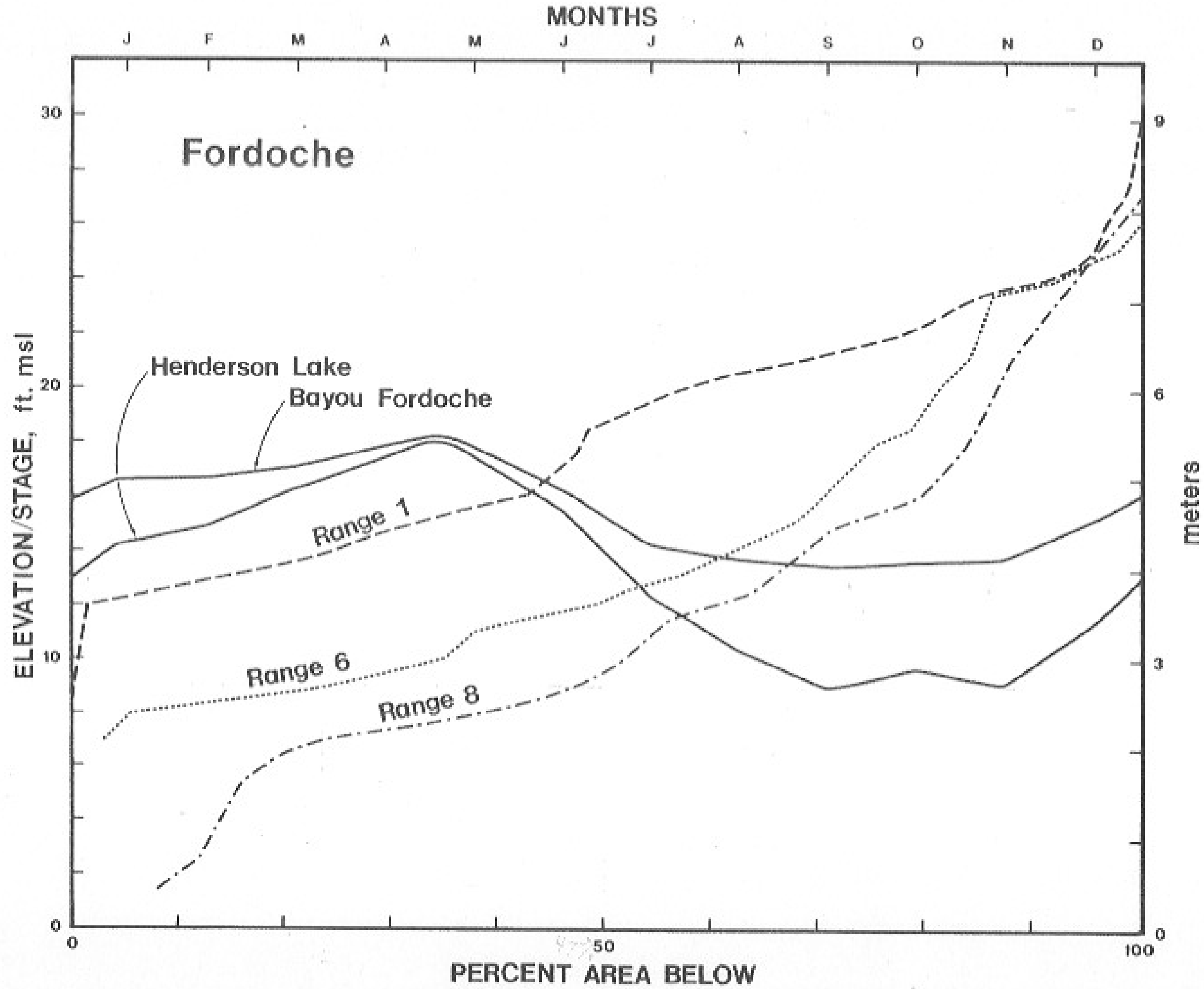

Figure 5-2. Average annual stage hydrographs for Henderson Lake and Bayou Fordoche, and elevation frequency curves for the upper (range 1), central (range 6), and lower (range 8) parts of the Fordoche Management Unit.

southern parts is submerged. Dewatering during low stages is nearly complete in northern Fordoche, while some 30 to 40 percent of the area, including the lake, remains submerged in the central and southern parts. Water depths in the northern swamp generally do not exceed 1 m, while southward they increase to as much as 2.5 m during spring flooding.

An additional aspect is revealed by the shape of the hydrograph. One notices that water levels rise relatively slowly from January to April so that about 50 percent of the northern swamp and 70 percent of the southern swamp are submerged over the first four or five months of the year. Subsequent dewatering is seen to be much more rapid.

The hydrologic regime is summarized with regard to hydroperiod in Table 5-1. Based on the hydrographs and hypsometric curves, the period and extent of flooding were calculated for the upper, middle, and lower parts of Fordoche. Selected hydroperiod lengths relate to biological habitat and management objectives as set forth in the previous report (van Beek et al., 1976) and Table 5-2.

HABITAT

Prior to construction of artificial levees in the early 1930's, the Fordoche unit contained well-drained lands along the natural levee ridges of the Atchafalaya River, Bayou Courtableau, and Butte La Rose Bay (Figure 5-1), with backswamp occupying most of the remaining area westward toward the Teche levee ridges. In the western part of the unit, north-south alignment of remnant river channels facilitated drainage of the backswamp into Butte La Rose Bay and the Atchafalaya River. On the east side, drainage was much less efficient and natural ponding had led to development of a lake that coincided approximately with the southern half of the present Henderson Lake. A mixed hardwoods vegetation covered portions of the Atchafalaya River and Bayou Courtableau natural levee which had not been cleared for agriculture. Cypress-tupelo associations occupied the lowlands subject to the longest period of flooding. Lands along the toe of the natural levee, representing a transitional zone, contained a swamp-mixed hardwood association. The hydrologic regime was probably the dominant factor governing the distribution of vegetation in this natural environment.

By the early twentieth century, this pattern had been significantly altered by lumbering and oil exploration, especially in the southern two-thirds of the unit. The cypress industry had removed all marketable logs, leaving only stumps and unsound cypress trees. The second-growth forests that emerged in the scarred backswamp contained some cypress, but were composed mainly of willow (Salix nigra) and cottonwood (Populus deltoides). Spoil banks resulting from pipeline canals and location dredging were also colonized by vegetation associations dominated by willows and cottonwood.

Completion of the West Atchafalaya Basin Protection Levee which further blocked natural southward drainage, and construction of the Atchafalaya River

247.1 ac/km²

TABLE 5-1. EXTENT AND DURATION OF FLOODING, FORDOCHE MANAGEMENT UNIT

	PERIOD FLOODED*** (Months)	AREA* %	AREA** (km^2)	ELEVATION* (m)
NORTHERN FORDOCHE (Range 1)	0 - 1	52	67	> 5.3
	1 - 4	5	7	4.9 - 5.3
	4 - 8	17	22	4.3 - 4.9
	8 - 11	5	7	4.1 - 4.3
	11 - 12	21	27	< 4.1
CENTRAL FORDOCHE (Range 6)	0 - 1	26	20	< 5.2
	1 - 4	7	6	4.5 - 5.2
	4 - 8	30	24	3.5 - 4.5
	8 - 11	11	9	2.8 - 3.5
	11 - 12	26	21	< 2.8
SOUTHERN FORDOCHE (Range 8)	0 - 1	17	10	> 5.2
	1 - 4	11	7	4.5 - 5.2
	4 - 8	18	10	3.5 - 4.5
	8 - 11	6	4	2.8 - 3.5
	11 - 12	49	29	< 2.8
TOTAL	0 - 1	36	97	
	1 - 4	7	20	
	4 - 8	21	56	
	8 - 11	7	20	
	11 - 12	29	77	

173 = 43,000 ac
273 = 67,000

*Estimated from given range line

**Area for given subunit is estimated from area percent at a given range line

***Estimated from stage data

TABLE 5-2. RELATIONSHIP BETWEEN FLOODING CHARACTERISTICS AND BIOLOGICAL CONDITIONS AND VALUES

Hydroperiod Class Interval	Class V 11-12 mos.	Class IV 8-11 mos.	Class III 4-8 mos.	Class II 1-4 mos.	Class I 0-1 mos.
Flooding Characteristics	Permanent and subpermanent aquatic habitat; lakes, bayous, main river channels.	Swampland subject to extended flooding. Flooding may begin in November and last through July or later. Wholly or partly dewatered from late summer to early fall. Deep swamps.	Moderately flooded swampland. Flooding may begin in December and extend through July. Typically dry mid-summer to mid-fall. Intermediate swamps.	Swampland subject to a relatively short flood period. Land is usually flooded only during the spring months during highest river stages. Shallow swamps.	Land which is not flooded or only briefly flooded during the average water-year. Flood period, if any, usually in mid-spring, crests of natural levees and spoil banks.
Plant Communities	Epiphytes of tree covered areas: Spanish moss, lichens, mosses, resurrection fern. Overstory: water tupelo, baldcypress; willow along river channels. Understory trees and shrubs: buttonbush. Floating aquatic plants: water hyacinth, water lettuce, frogbit, duckweed, Riccia, Azolla. Submerged aquatic plants: coontail, water celery, Egeria, fanwort, Hydrilla, Chara.	Epiphytes: Spanish moss, resurrection fern, lichens, mosses. Overstory trees: water tupelo, baldcypress. Understory trees and shrubs: buttonbush, water elm. Herbaceous forms: Floating aquatics - water hyacinth, water lettuce, duckweed, frogbit, Riccia, Azolla. Submerged aquatic - coontail. Emergent aquatics - arrow-arum, pickerelweed.	Epiphytes: Spanish moss, lichens, mosses, resurrection fern. Overstory trees: baldcypress, water tupelo, pumpkin ash, green ash, bitter pecan, black willow and sandbar willow in areas where sedimentation is active. Understory trees and shrubs: buttonbush, Virginia willow, silver bells, water elm. Herbaceous forms: Floating aquatics - water hyacinth, water lettuce, frogbit, duckweed, Riccia, Azolla. Submerged aquatics - coontail. Emergent aquatics - lizard's tail, arrow-arum, spider lily, arrowhead.	Epiphytes: Spanish moss, lichens, mosses, resurrection fern. Overstory: baldcypress, green ash, red maple, bitter pecan; black willow, cottonwood, and sycamore may become established where sedimentation is strong. Understory trees and shrubs: wax myrtle, palmetto, Crataegus Spp., swamp privet, red bay. Vines: rattan, pepper vine, Trachelospermum. Herbaceous Forms: Floating aquatics - water hyacinth, water lettuce, frogbit, duckweed, Riccia, Azolla. Emergent aquatics - lizard's tail, Polygonum Spp., royal fern, false nettle.	Epiphytes: Spanish moss, lichens, mosses, resurrection fern, mistletoe. Overstory trees: cottonwood, black willow and sycamore where sedimentation is active; water oak, overcup oak, American elm, hackberry, sweetgum, nuttall oak; live oak on some higher sites. Understory trees and shrubs: box elder, deciduous holly, wax myrtle, Crataegus Spp., Elderberry, pokeweed. Vines: poison ivy, rattan, muscadine, eardrop vine, Smilax Spp., dewberry, crossvine, trumpet creeper, Japanese honeysuckle. Herbaceous forms: false nettle, butterweed, Spilanthes, Oplismenus.
Importance to Fish and Wildlife	Permanent habitat for fishes and other aquatic fauna. Lakes and bayous are spawning areas for sport and commercial fishes. River channels provide habitat for fishes preferring a current (channel catfish, striped bass, paddlefish). Crawfish population small as compared to swamp areas. Habitat for minks, otters, nutria, raccoons, wading birds, waterfowl, snakes, alligators, frogs.	Alternately part of the aquatic and terrestrial environment. Feeding area for adult and juvenile fishes. Long hydroperiod assures time for growth of juvenile fishes. Crawfish are exposed to prolonged predation. Habitat for furbearers, wading birds, some waterfowl. May serve as habitat for terrestrial species (deer, rabbits) when dry.	Intermediate hydroperiod swamps are utilized as feeding areas by adult fishes and are important as nursery areas for young of year fishes. Hydroperiod is long enough to allow for growth and sexual maturity of crawfish and short enough to prevent over-predation by aquatic predators: crawfish burrow into bottom muds during dry periods. Intermediate hydroperiod swamps serve as habitat for aquatic mammals, birds, reptiles and amphibians when flooded and for terrestrial species when drained.	Swamps serve as a nursery area for juvenile fishes and as a feeding area for adult fishes when flooded. Shallow swamps may also serve as a spawning area for certain fishes (e.g., gars, carp). Crawfish utilize short hydroperiod swamps as feeding and growing areas. Utilized by aquatic species of wildlife when flooded and by terrestrial species when dry.	Essentially dry land environments, these areas may be utilized by aquatic fauna, including fishes and waterfowl, during the brief flood period. Much of the northern end of the basin consists of this habitat type in the early stages of succession. Wildlife present includes deer, bear, rabbits, squirrels, bobcats, skunks, armadillos, turkey, woodcocks and many non-game species. Certain of the higher ridges and islands in the lower end of the basin support this type of habitat.
Management Objectives	1. Maintenance of aquatic area. 2. Water quality protection and enhancement. 3. Reduction of sedimentation rate. 4. Control of aquatic weeds. 5. Reduction of extreme flood volume.	1. Maintenance of a water depth of at least 4 ft. during months of crawfish trapping. 2. Improvement of oxygen content of waters to reduce trap mortalities to crawfish. 3. Improvement of extent of dewatering in late summer and early fall. 4. Reduction of sedimentation rate. 5. Reduction of extreme flood volume. 6. Control of aquatic weeds.	1. Regulation of hydroperiod to assure adequate conditions for crawfish and fish reproduction. 2. Reduction of sedimentation rate. 3. Control of aquatic weeds. 4. Reduction of extreme flood volume.	1. Reduction of extreme flood volume. 2. Reduction of sedimentation rate.	1. Reduction of extreme flood volume. 2. Reduction of sedimentation rate.

levees, which blocked Bayou Courtableau and Butte La Rose Bay, further impounded the Fordoche unit. As a result, a larger portion of the unit became permanently flooded, especially after installation for fisheries purposes of a 2.25-m MSL sector gate in the West Atchafalaya Basin Protection Levee borrow pit. Henderson Lake increased to a minimum area of 20 km^2, and an area ranging from 120 to 200 km^2 experienced a longer hydroperiod than had previously existed (Lantz, 1974). As suggested by the following map comparison, the new hydrologic regime is largely responsible for maintaining the type of second-growth forest that emerged after the area was lumbered. Characteristics of this regime were already summarized in the previous section and Table 5-1.

On the basis of topographic and hydrologic data, extent and duration of flooding could be mapped. Figure 5-3 shows the hydroperiods as experienced by various parts of the Fordoche unit. The area of shortest hydroperiod is found along the Atchafalaya River natural levee and abandoned distributary and crevasse deposits. Hydroperiods increase in duration westward, away from the levee flank, and southward, in response to general surface gradient and the increased ponding effect.

A comparison of the spatial distribution of areas subject to a given hydroperiod with that of vegetation (Figures 5-3, 5-4) generally supports a correlation that has been observed by others in similar wetland environments (Penfound, 1952; U.S. Department of Agriculture, 1973). The correlation applicable in the Fordoche unit is summarized in Table 5-3.

TABLE 5-3. RELATIONSHIP BETWEEN DURATION, AVERAGE DEPTH OF FLOODING, AND VEGETATION ASSOCIATIONS IN FORDOCHE MANAGEMENT UNIT

Duration of Flooding (months)	Average Depth of Flooding (m)	Vegetation Associations (EROS, 1975)
0 - 1	0.1	mixed hardwoods
1 - 4	0.4	swamp/mixed hardwoods
4 - 8	0.8	swamp/mixed hardwoods willow/cottonwood
8 - 11	1.0	willow/cottonwood
11 - 12	>1.0	cypress/tupelo

Many of the natural levee lands experiencing a hydroperiod of 0-1 month are well above 5.4 m MSL and are no longer subject to annual flooding. Consequently, a large portion of this rich alluvial soil has been cleared for agriculture, as shown in Figure 5-4. The remaining area supports mixed hardwood forests. The areas with hydroperiods of 1-8 months represent transitional zones as evidenced by the swamp/mixed hardwood forests. Hydroperiods of 8-12 months are tolerated only by cypress/tupelo gum and willow/cottonwood associations.

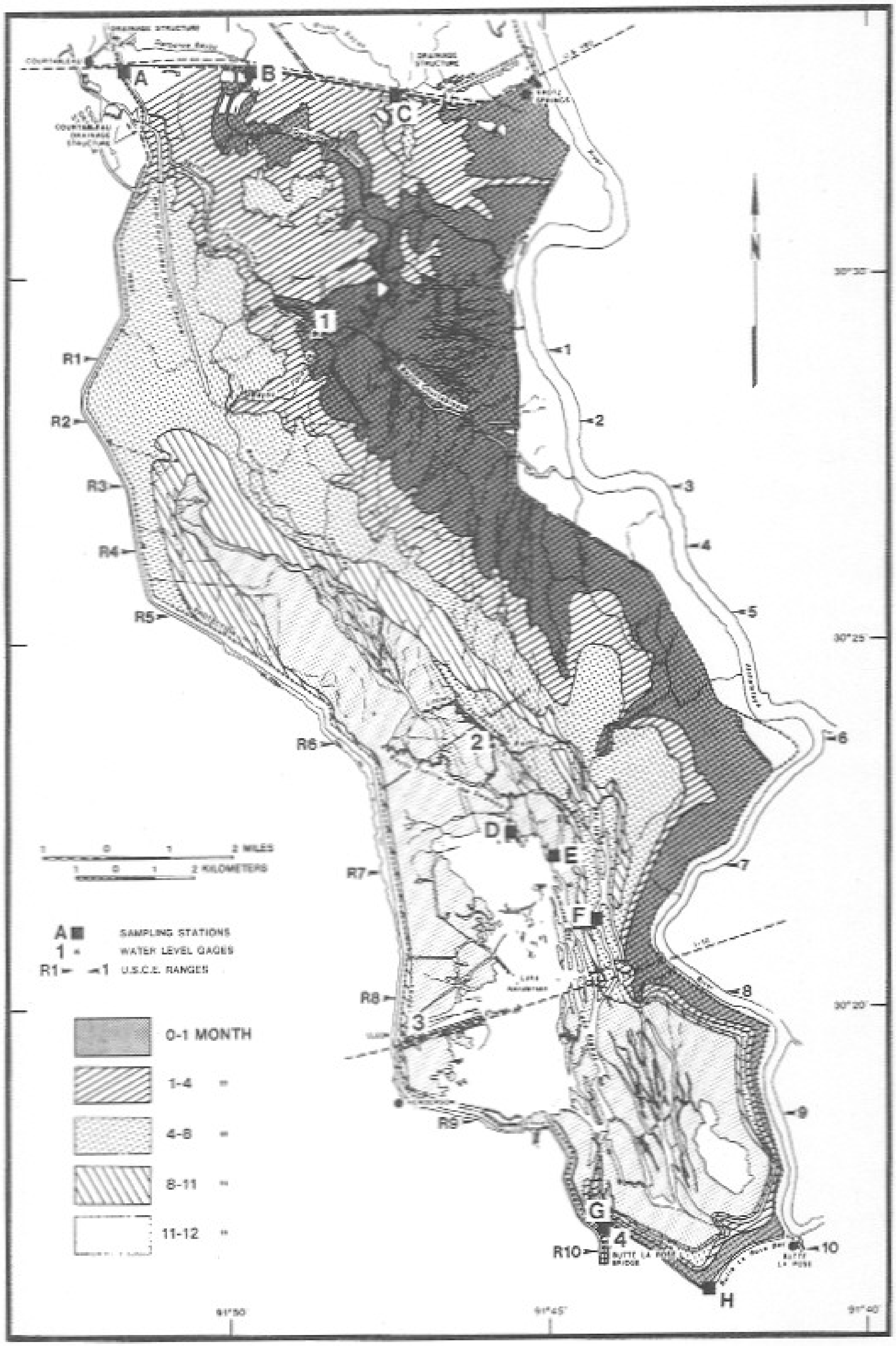

Figure 5-3. Extent and duration of flooding, Fordoche Management Unit.

all dredging in
Fordoche as BLHW HUV = 64.3 HU's/ac

BLH 26,344
WS 5,501
CWS 25,340

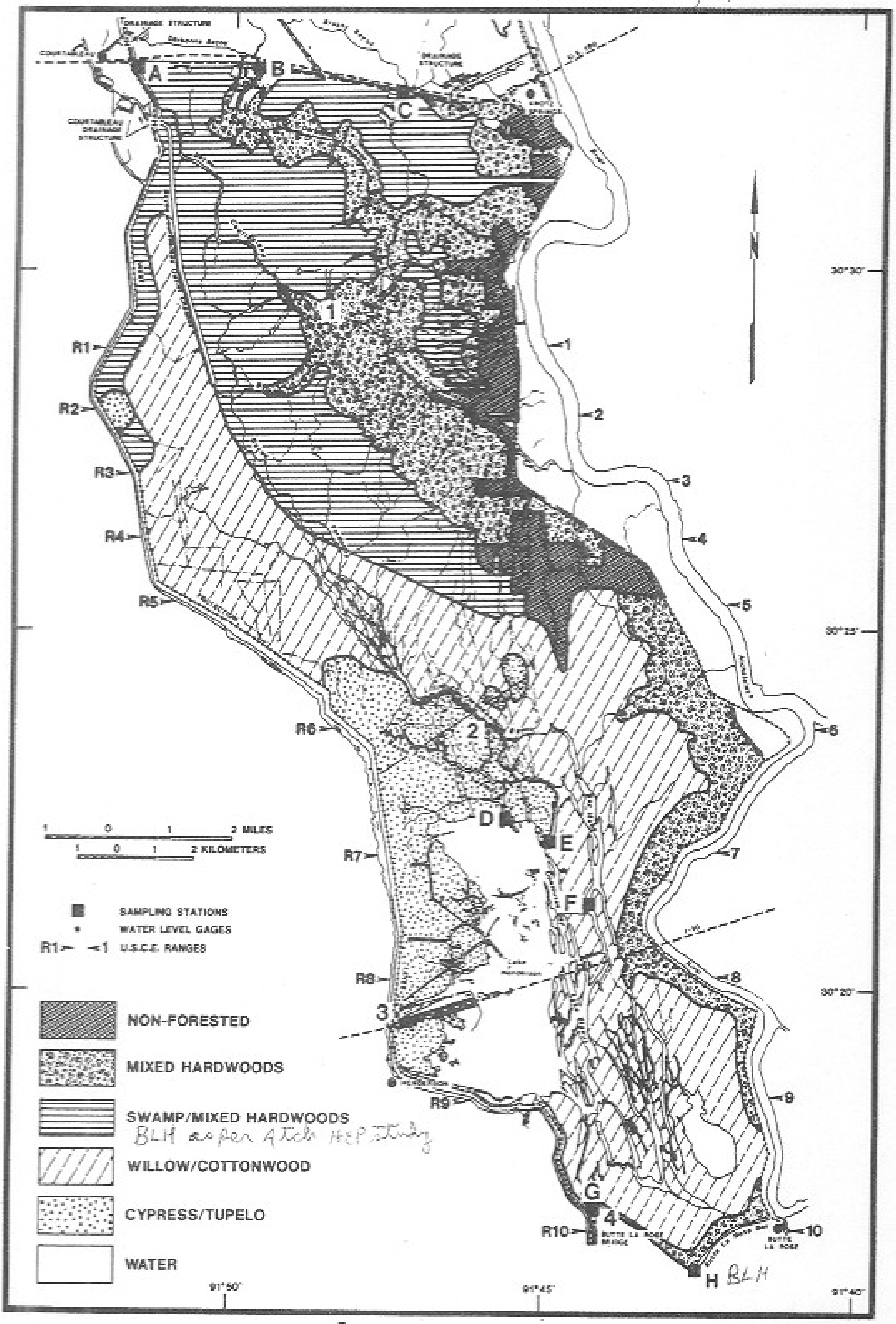

Figure 5-4. Distribution of vegetation associations, Fordoche Management Unit (after EROS, 1975).

Lumbering in the early twenties is believed to have been partly responsible for the invasion of the willow/cottonwood association, which presently predominates. Lumbering techniques, especially clear-cutting, provided both open conditions and exposed mineral soils favorable for willow germination and growth. On the other hand, it is generally believed that tupelo/gum and cypress are the climax species in deep swamp environments and "will regenerate usually to what they were before cutting, although willow may temporarily dominate cut-over areas" (U.S. Department of Agriculture, 1973). It should be added, however, that the greater stage fluctuations that came with increased diversion of Mississippi River water and floodway construction and impoundment of the Fordoche unit placed additional constraints on the lumbered area with regard to cypress regeneration.

The only portion of the Fordoche area which contains dense stands of cypress and scattered tupelo gum is the southwestern perimeter of Henderson Lake. Since these trees are secondary growth and the area is generally submerged throughout the year with stage variations up to 4 m, these stands of cypress/tupelo gum must be attributed to regeneration during pre-floodway conditions or regeneration from stumps. Possibly this was one of the earlier areas lumbered.

WATER AND SEDIMENT BUDGET, 1975-1976

Much insight into the hydrologic processes that govern the Fordoche regime can be obtained from inspection and comparison of detailed stage hydrographs for the area. For this purpose, 1975-1976 stage data were obtained for the following U.S. Army Corps of Engineers gaging stations (Figure 5-5): Bayou Fordoche (1) in the upper part of the unit, Cleon (3) and West Atchafalaya Basin Protection Levee borrow pit at Butte La Rose Bridge (4) in the lower part of the unit, and Atchafalaya River at Butte La Rose. Plotted in the form of stage hydrographs (Figure 5-6), these data immediately suggest the nature of relationships between water levels in the Fordoche unit, river stages, and inflow of drainage water.

The Atchafalaya River shows a low-stage period from September through November, an accelerating rise from November through March, and a decelerating recession from April through July. For further discussion and comparison, the hydrograph is divided into five intervals according to direction and rates of Atchafalaya River stage changes. Intervals are marked I through V (Figure 5-6). River levels during most of Period I were below crest level of the borrow pit sector gate. Therefore, inflow of river water was largely prevented, as were river-caused stage fluctuations.

For the upper and lower parts of the Fordoche unit, behavior of water levels differs in several respects, both when compared to each other and when compared with river stages. The most striking aspect of the hydrograph for the Upper Fordoche area (Bayou Fordoche, Figure 5-6) is a large number of peaks, each showing a rapid rise and gradual recession. The reason for these peaks becomes obvious when comparing the hydrograph with the precipitation data and with inflow from the Courtableau Drainage Structure. Both

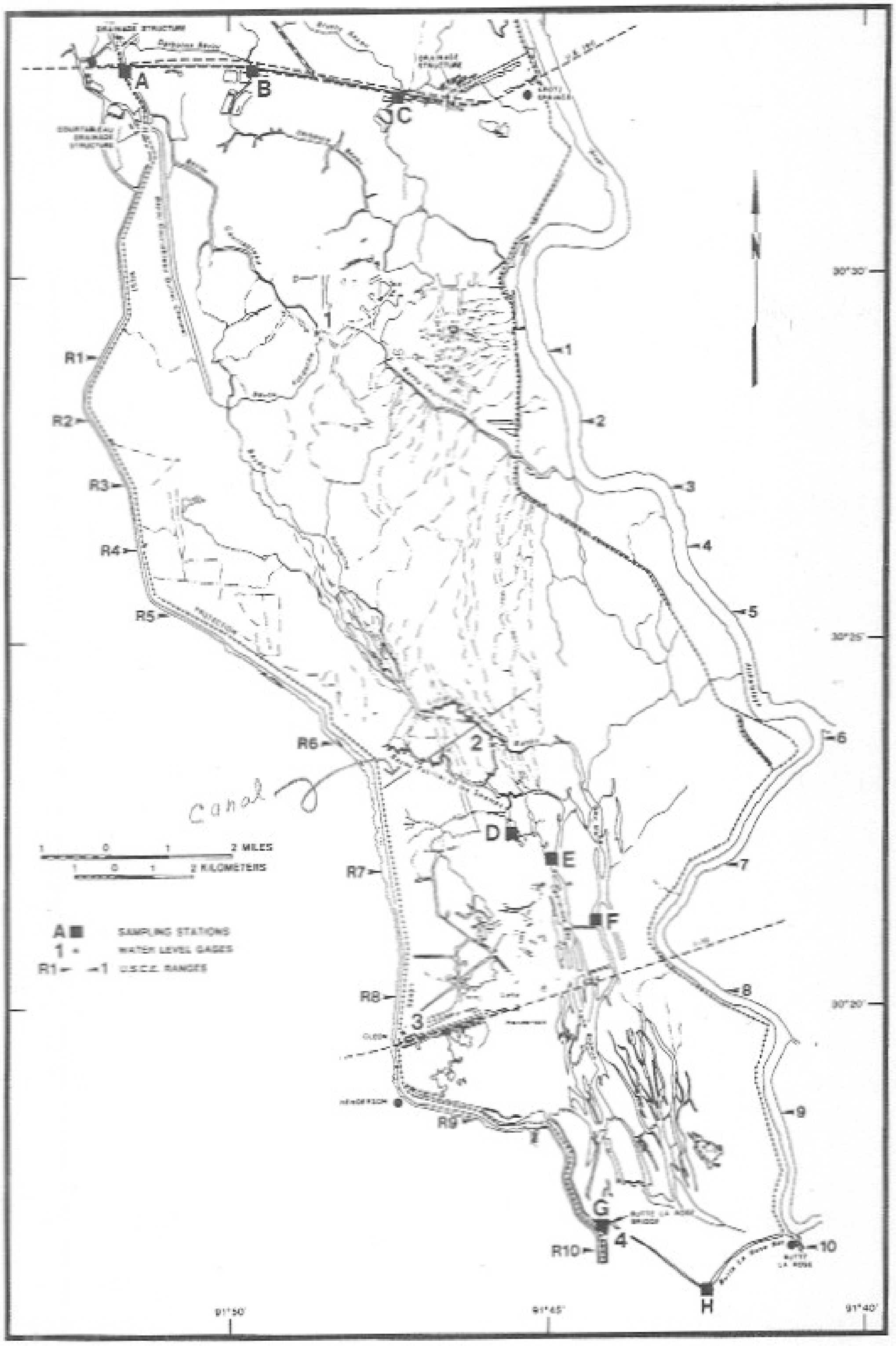

Figure 5-5. Location of water level gages, topographic survey ranges, and discharge-sediment measurement stations in Fordoche Management Unit.

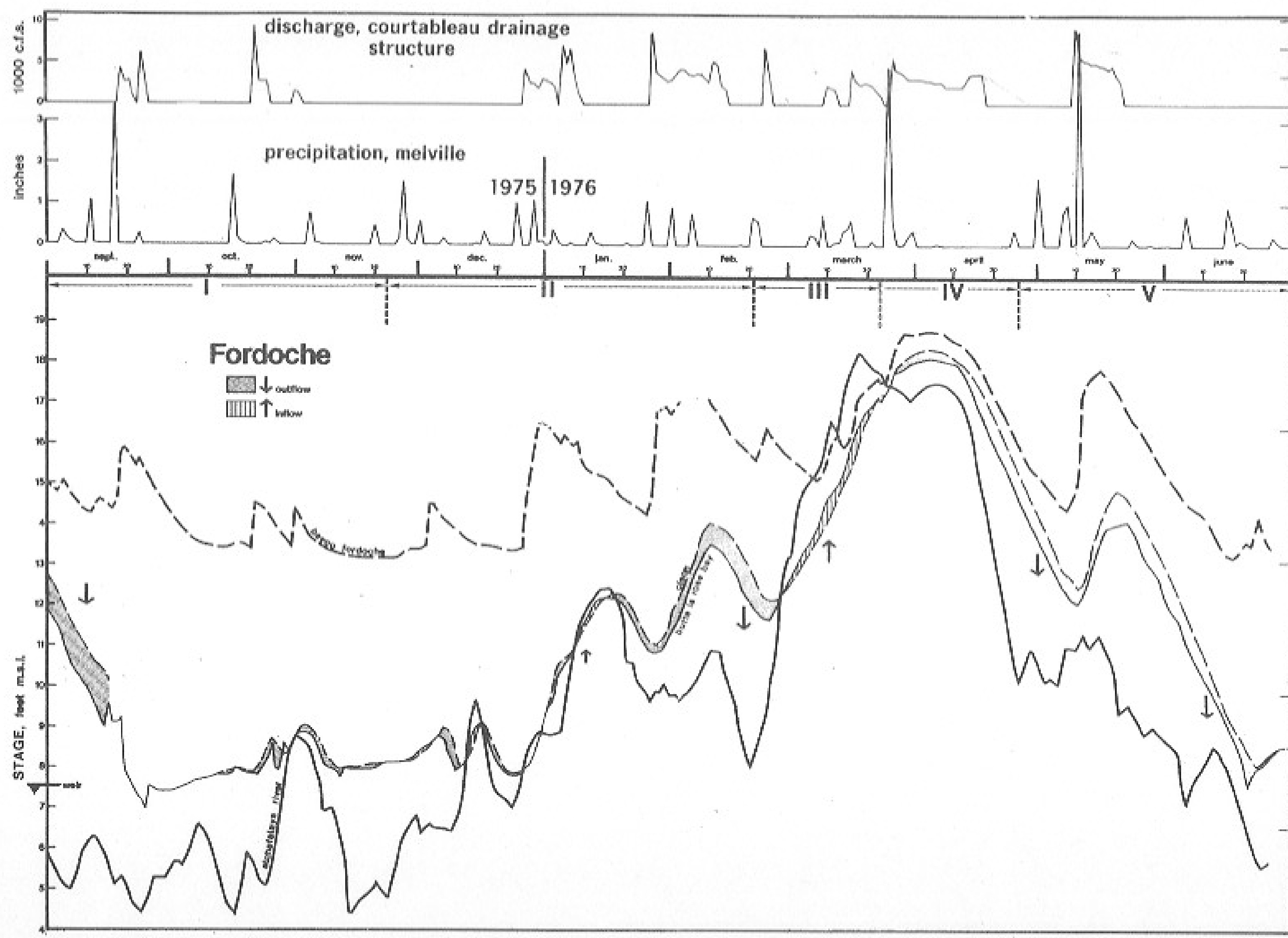

Figure 5-6. Stage hydrographs for Upper Fordoche (Bayou Fordoche) and Lower Fordoche (Butte La Rose bridge and Cleon) and the Atchafalaya River, discharge hydrograph for Courtableau Drainage Structure, and precipitation at Melville, Louisiana.

are plotted as a time series above the hydrograph in Figure 5-6. One notices that at the onset or immediately following major precipitation, the drainage structure is opened, providing a much larger inflow into the sub-unit than would result from local runoff. Consequently, a rapid rise in swamp water levels is produced, in particular because transfer of water from the upper to the lower part of Fordoche is slow due to hydraulic constraints.

The slow rate at which the Upper Fordoche swamps drain into Henderson Lake relative to the rapid rate at which water levels fall in Lower Fordoche results in a considerable southward gradient. In Figure 5-6, one notices that as the Henderson Lake area is draining rapidly through the borrow pit, water levels in the Upper Fordoche area recede much slower, resulting in a 1.5-m difference in water level between the Bayou Fordoche and Henderson gages. The resultant gradient is sustained throughout Period I, as is the associated southward movement of water. Invariably, flow measured at the mouth of Bayou Fordoche was into Henderson Lake, while at the borrow pit outlet (Butte La Rose Bridge), flow was outward almost continuously.

The effect of the Courtableau structure becomes more pronounced during the winter (Period II) when frontal rainfall intensifies. Introduction of runoff water into Upper Fordoche produces rapid rises in January and February. As water moves toward the lower part of the area, an additional aspect of water introduction through the Courtableau structure becomes apparent. This concerns the interaction with rising Atchafalaya River waters. The introduced runoff tends to amplify rises produced by the Atchafalaya River, and interaction is such that rising river stages prevent outflow of much or all of the drainage water. At the same time, accumulated runoff prevents river waters from flowing into the Fordoche area. Thus, during January and February, a 1.2-m net rise occurred, which was almost entirely attributed to inflow from the Courtableau Drainage Structure and local runoff. During those months, water stages were maintained above those of the Atchafalaya River so that the outflow that occurred during the previous four months was sustained despite rising river stages (Figure 5-6).

During Period III, introduction of drainage water was insufficient to offset the accelerated rise of Atchafalaya River stages. In March, a net rise of 1.5 m occurred in Lower Fordoche, part of which was contributed by river waters entering Henderson Lake. On the basis of flow direction and gradient observations, river water is believed not to have moved northward beyond Henderson Lake. Since stages increased more rapidly in the Henderson area than in northern Fordoche, the gradient between the two areas was all but eliminated at the time of flood stage (Figure 5-6).

Water levels remained at peak stage for about two weeks in April. During that time, introduction of drainage water and runoff was sufficient to establish a southward gradient and produce outflow from the unit. As recession of stages began, outflow was accelerated and continued even during a temporary May rise. The above pattern was sustained through the month of June

In summary, the hydrographs show that during the 11-month study period, a net rise and fall of 3 m occurred. Water requirements for this phenomenon were met largely by local runoff and inflow from the Courtableau Drainage Structure, while additional amounts were provided when Atchafalaya River stages also forced river water into the Fordoche basin. During the 11 months considered here, the regime was such that outflow from the system predominated for 6 months, flow was variable for 4 months, and inflow from the river occurred for 1 month. Of particular importance is that interaction between rising river stages and rising stages in Henderson Lake due to drainage water arrival was such that outflow continued even during significant rises in Atchafalaya River stages.

To further characterize water movement with regard to the Fordoche area, a number of flow conditions considered typical are given in Table 5-4. The data pertain to the borrow pit where it enters the Fordoche unit, to Bayou Fordoche where it enters Henderson Lake, and to Little State Canal where it crosses the northern boundary of the Fordoche unit (Stations G, D, A: Figure 5-5). A notable occurrence at Station G is the difference between suspended load concentrations for Period III, when Atchafalaya River water is entering the unit, and the remaining time, when outflow dominates. Bayou Fordoche is seen to have a rather steady southward flow except during Period III, when rising stages due to river water inflow eliminate the gradient. Inflows at Little State Canal appear to be very small, especially since these represent the total of measured inflow across the northern boundary. Not included in the tabulation are the inflows from the Courtableau Drainage Structure since these will be discussed in subsequent paragraphs.

Combining all available hydrologic data for the 1975-1976 period allows estimation of respective contributions to the flooding process by local precipitation, introduced drainage, and the Atchafalaya River. For this purpose and in recognition of a surface-water gradient, the Fordoche area is divided into two nearly equal-sized areas: Upper, or northern, and Lower, or southern Fordoche. U.S. Army Corps of Engineers survey range 5 (Figure 5-5) was selected as the dividing line; water levels throughout Upper Fordoche were assumed to equal those recorded at the central Bayou Fordoche gage (1) and water levels in the area below range 5 were assumed to equal the average of the Opelousas Bay (4) and Cleon (3) gages. Only precipitation and monthly evapotranspiration rates were applied equally to each area. Precipitation data used were those at Melville, Louisiana, immediately to the north of the Fordoche area. Evapotranspiration rates were those determined for Melville through water-balance calculation in a previous study (van Beek _et al_., 1976).

Using topographic data from the U.S. Army Corps of Engineers survey Ranges 1 through 8, storage curves were developed for both Upper and Lower Fordoche (Figure 5-7). Time periods within which water-level changes were of a nearly constant rate and single direction were then used as intervals over which storage changes were determined. Generally, these intervals extended from one to four days. For each of those intervals, precipitation rates and the inflow of water through the Courtableau Drainage Structure were calculated. For the latter, U.S. Army Corps of Engineers discharge rating curves (Communication with U.S. Army Corps of Engineers, 1976) were used in

TABLE 5-4. CHARACTERISTIC FLOWS IN THE FORDOCHE MANAGEMENT UNIT

STATION	PERIOD	DISCHARGE m^3/s	DIRECTION	AVERAGE VELOCITY	SUSPENDED SEDIMENT g/l SAND	SUSPENDED SEDIMENT g/l SILT & CLAY
G	I	38	out	0.35	0	0.019
	II	102	out	0.62	0.006	0.076
	III	81	in	0.38	0.003	0.273
	IV, V	110	out	0.59	0.005	0.043
D	I, II, IV, V	12	south	0.06	0	0.075
	III	3	south	0.02	0	0.043
A	I, II, III, IV, V	5	south	0.31	0	0.156

G = Borrow Pit where it enters the Fordoche Unit
D = Bayou Fordoche where it enters Henderson Lake
A = Little State Canal where it crosses the northern boundary in the Fordoche Unit

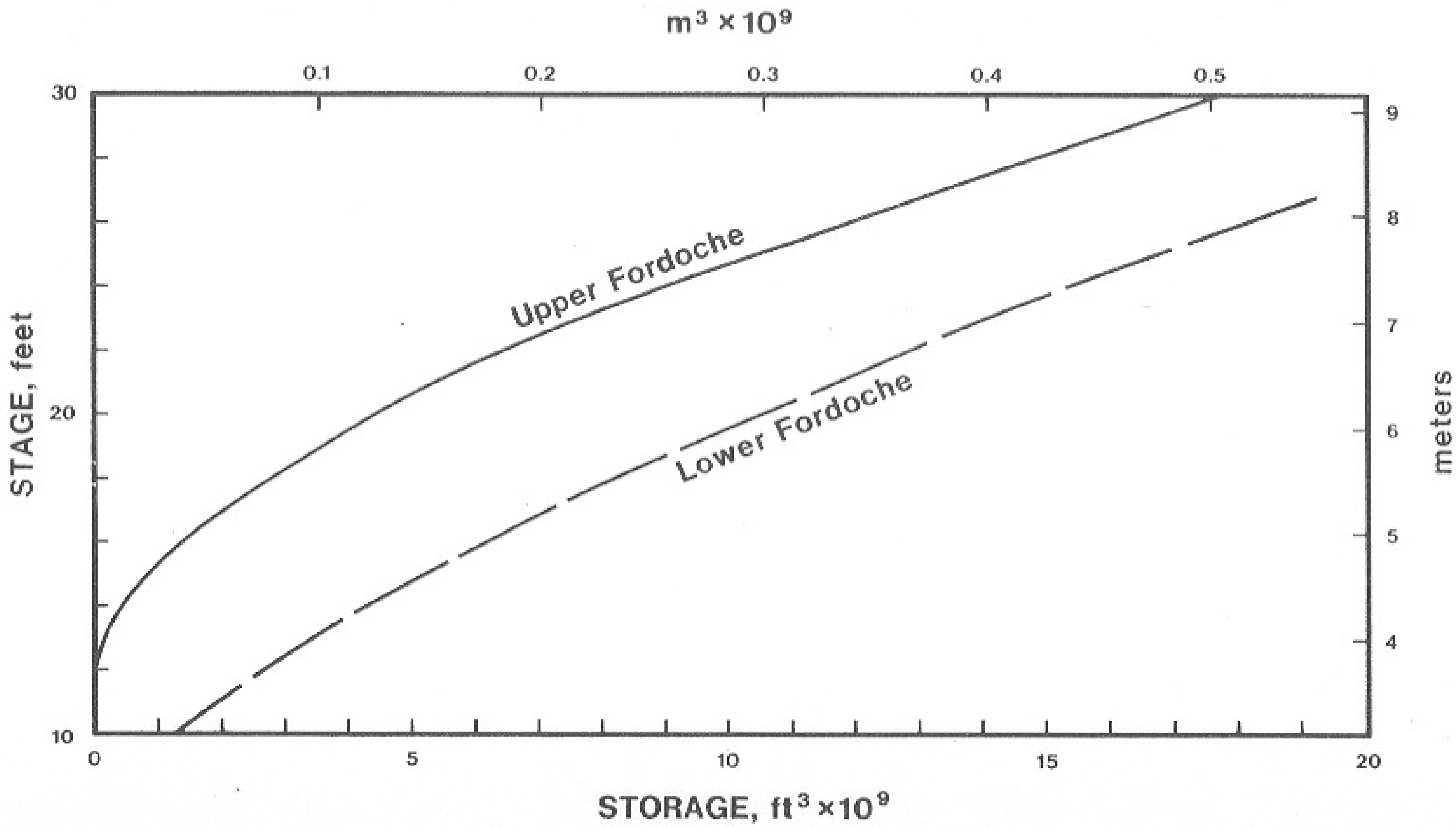

Figure 5-7. Storage curves for Upper and Lower Fordoche.

combination with stage data from the following two gages: Bayou Courtableau above Drainage Structure and Bayou Courtableau Outlet Channel near Southeast Wing Wall. Through stepwise calculation, storage changes in Upper Fordoche (ΔS_{UF}) and Lower Fordoche (ΔS_{LF}) as obtained from stage changes were then defined in terms of the following variables:

x_1 = precipitation excess in Upper Fordoche;
x_2 = inflow from Courtableau Drainage Structure into Upper Fordoche;
x_3 = flow into or from Lower Fordoche ($x_3 = \Delta S_{UF} - x_1 - x_2$);
x_4 = precipitation excess in Lower Fordoche;
x_5 = flow into or from Upper Fordoche ($x_5 = -x_3$); and
x_6 = flow from or into Atchafalaya River via borrow pit ($x_6 = \Delta S_{LF} - x_4 - x_5$).

Results of the above calculations are summarized in Table 5-5 according to the time periods I-V. It should be stressed beforehand that the obtained volumetric values can be only first approximations because of the assumed conditions and the limited data control. Comparisons of instantaneous discharges calculated from flow measurements and average discharges calculated from storage change show a general agreement ($\pm$30 percent). Also, the direction of flow at the borrow pit outlet as calculated is in agreement with that recorded daily by the surface-water gradient between the two southernmost gages.

Assuming that the obtained values are an accurate reflection of at least relative magnitude and direction of water movement, a number of conclusions may be derived from Table 5-5 for the 1975-1976 study period. First, the data suggest that river water contributed very little to flooding of Upper Fordoche. Of the total water input into that area, 83 percent was introduced through the Courtableau structure, and 11 percent was derived from local rainfall. Thus, only 6 percent of the water introduced into Upper Fordoche came from the Atchafalaya River and then only after having been mixed with waters of Lower Fordoche. Flooding of Upper Fordoche thus is accomplished primarily by ponding of water introduced through the Courtableau structure and, to some extent, local rainfall. Ponding occurs as a result of rising river stages.

With regard to the Lower Fordoche area, the data corroborate the earlier conclusions concerning interaction between rising Atchafalaya River stages and water released from Upper Fordoche. The Atchafalaya River contributed only sixteen percent of the total water input into the Lower Fordoche subunit. Local precipitation accounted for 9 percent, and water released from Upper Fordoche supplied the remaining 75 percent. Inflow of river water was at a maximum during the stage rise that occurred in Period III. However, even then river water accounted for only about half (53 percent) of the inflow that produced the rise. The other half was provided by water released from the Upper Fordoche area and by local precipitation. When considered along with the information concerning the limited northward flow into Upper Henderson, this suggests that river water remained largely confined to Henderson Lake.

TABLE 5-5. WATER INPUT, FORDOCHE UNIT, 1975-1976 (in $m^3 \times 10^6$)

PERIOD		UPPER FORDOCHE			LOWER FORDOCHE			FORDOCHE TOTAL		
		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
I	in	24.3	97.8	23.0	22.4	106.1	34.8	46.7	97.8	34.8
	out	-22.9		-106.1	-21.2	-23.0	-185.9	-44.1		-185.9
II	in	28.3	303.4	21.1	26.1	321.6	42.1	54.4	303.4	42.1
	out	-3.4		-321.6	-3.2	-21.1	-304.2	-6.4		-304.2
III	in	8.9	90.0	13.2	8.2	72.2	90.7	17.1	90.0	90.7
	out	-1.8		-72.2	-1.6	-13.2	-24.6	-3.4		0.0
IV	in	17.2	185.9	0.2	15.9	190.4	0.0	33.1	185.9	0.0
	out	-4.5		-190.4	-4.2	-0.2	-213.0	-8.7		-213.0
V	in	27.9	157.0	8.9	25.8	157.0	13.6	53.8	157.0	13.6
	out	-25.8		-157.0	-23.8	-8.9	-414.7	-49.6		-414.7
TOTAL	in	106.6	834.1	66.4	98.4	847.3	182.2	205.1	834.1	181.2
	in %	11	83	6	9	75	16	17	68	15

x_1 = precipitation excess in Upper Fordoche
x_2 = inflow from Courtableau Drainage Structure into Upper Fordoche
x_3 = flow into or from Lower Fordoche ($x_3 = \Delta S_{UF} - x_1 - x_2$)
x_4 = precipitation excess in Lower Fordoche
x_5 = flow into or from Upper Fordoche ($x_5 = -x_3$)
x_6 = flow from or into Atchafalaya River via borrow pit ($x_6 = \Delta S_{LF} - x_4 - x_5$)
x_7 = total precipitation excess in Fordoche Management Unit ($x_7 = x_1 + x_4$)
x_8 = inflow from Courtableau Drainage Structure ($x_8 = x_2$)
x_9 = water exchange with Atchafalaya River via borrow pit ($x_9 = x_6$)

Another matter of interest related to the water balance is the extent to which inflow of water exceeded the volume required to produce a gradual rise and fall between the same maximum and minimum. Also important is the amount of flushing, an estimate of which can be obtained by comparing the above excess with the volume of water present in the swamp basin. Table 5-6 allows the above comparisons. It shows that a gradual rise and fall of equal amplitude, but without fluctuations, could have been obtained with approximately one-fourth of the flow that entered the Fordoche Unit. Most of the excess flow was introduced during the large amplitude fluctuations of Period II.

Flow introduced in excess of volumes needed to produce observed net water-level changes is seen to largely exceed the volume of water already in storage. Though much of this excess water resulted in superimposed, individual rises, mixing and subsequent release must have produced considerable turnover of swamp waters since the largest part of introduced water enters in the upper area and moves through the Fordoche Unit.

Having obtained an estimate of river water inflow into the Fordoche Unit, an approximate value can also be derived for associated sediment introduction. In order to make such an approximation, a sediment-load discharge relationship was used that is based on the combined data for Fordoche and Buffalo Cove. Due to dominance of outflow and limited sampling frequency, sediment-load data for Fordoche alone were insufficient. However, the available data were found to follow the discharge-sediment load relationship determined for Buffalo Cove. Introduced sediment load was estimated on the basis of average inflow over the same short time intervals used in the water balance calculation. The obtained values are summarized in Table 5-7 by the stage-related time intervals. However, this calculated sediment input does not represent total input.

Sediment is also introduced through the Courtableau Drainage Structure. Water entering through that structure constitutes primarily runoff from agricultural areas. Twice during a 1977 follow-up study, discharge measurements were made and integrated water samples obtained in the Courtableau Drainage Channel about 300 m below the structure while it was in operation. Sediment concentrations followed the load-discharge relationship referred to above and shown later in Figure 6-10. This allowed an estimate of sediment introduction through the Courtableau Structure. The obtained values are summarized in Table 5-8.

Comparison with Table 5-7 shows that, of the total water introduction into Fordoche during the study period, 32 percent was derived from the Atchafalaya River and 68 percent from outside agricultural drainage. However, as much as 91 percent of the estimated sediment introduction was through the Courtableau Structure. Since load-discharge relationships were found to be similar for both reports, this indicates that the higher sediment input through the Courtableau Structure is caused by higher average discharge rates resulting in higher concentrations of suspended sediment.

TABLE 5-6. COMPARISON BETWEEN ACTUAL FLOW AND MINIMUM FLOW NECESSARY TO PRODUCE OBSERVED NET STAGE VARIATION

PERIOD	STAGE VARIATION m		NEEDED WATER $m^3 \times 10^6$		PRECIPITATION SURPLUS $m^3 \times 10^6$	NEEDED INFLOW $m^3 \times 10^6$	ACTUAL INFLOW $m^3 \times 10^6$			EXCESS FLOW $m^3 \times 10^6$	VOLUME STORED $m^3 \times 10^6$
	Upper Fordoche	Lower Fordoche	Upper Fordoche	Lower Fordoche			Courtableau	Atchafalaya River	TOTAL		
	4.5	3.6									94.8
I			-18.4	-58.9	2.7	0.0	97.8	34.8	132.6	132.6	
	4.8	2.3									17.5
II			-1.4	67.4	47.8	19.6	303.4	42.1	345.5	325.9	
	3.9	2.8									33.5
III			79.3	164.2	13.8	229.7	138.9	90.8	229.7	0.0	
	5.5	5.5									320.0
IV			-58.0	-172.7	24.5	0.0	137.0	0.0	185.9	185.9	
	4.5	3.6									96.3
V			-21.2	-56.1	3.9	0.0	157.0	13.6	170.6	170.6	
	3.9	2.4									14.0
TOTAL						249.3			1064.3	815.0	

TABLE 5-7. SUSPENDED SEDIMENT INTRODUCED WITH RIVER WATER INTO THE FORDOCHE UNIT

Period	Suspended Sediment kg x 10^6	Water $m^3 \times 10^6$	Average Concentration kg/m^3
I	7.0	34.8	0.20
II	4.7	42.1	0.11
III	15.3	90.7	0.17
IV	0.0	0.0	-
V	2.0	13.6	0.15
Total	30.5	181.2	0.17

TABLE 5-8. SUSPENDED SEDIMENT INTRODUCED WITH AGRICULTURAL RUNOFF THROUGH COURTABLEAU DRAINAGE STRUCTURE

Period	Suspended Sediment kg x 10^6	Water $m^3 \times 10^6$	Average Concentration kg/m^3
I	49.0	97:9	0.5
II	115.0	293.8	0.4
III	20.0	90.0	0.2
IV	56.0	180.6	0.3
V	81.0	147.8	0.5
Total	321.0	810.1	0.4

SECTION VI

BUFFALO COVE

In this section, the Buffalo Cove study area will be analyzed. As in the preceding chapter, the topics discussed will be "Boundaries and Setting," "Annual Flooding," "Habitat," and "Water and Sediment Budget, 1975-1976."

BOUNDARIES AND SETTING

Like the Fordoche area considered in the preceding section, the Buffalo Cove area is located in the western half of the Atchafalaya Floodway some 50 km south of the Fordoche Unit. Although the entire management unit covers an area of 230 km^2, in the present study emphasis was placed on the northern half, which forms a well-defined sub-basin and hydrologic unit (Figure 1-1, 6-1). Boundaries are partially natural, partially man-made. To the east, the Buffalo Cove area is bounded by the spoil-elevated natural levee of the Atchafalaya Basin Main Channel and the natural levee ridge of West Fork Chicot Pass, an abandoned distributary of the Atchafalaya River. The northern boundary is formed by spoil-elevated, natural levee ridges of a number of old distributary channels that were linked through channelization to form the West Access Channel. The elevated left bank of Fausse Point Cut, an artificial channel, forms the western rim of the swamp basin, which converges farther south, in the vicinity of Buffalo Cove, with the West Fork Chicot Pass levee ridge. Surrounding the southern tip of Buffalo Cove is a developing natural levee ridge along a distributary channel referred to hereafter as Mud Lake Pass.

The Buffalo Cove swamp is part of an inter-levee basin that, prior to floodway construction, extended southeastward between natural levees of Chicot Pass (Main Channel) and its West Fork on the east side and the Bayou Chene (Access Channel) distributary network on the north side. With construction of the West Atchafalaya Basin Protection Levee and Fausse Point Cut, this basin was truncated, and development of a fully enclosed depression was initiated. At present, spoil-elevated levee ridges surround the Buffalo Cove sub-basin along most of its perimeter (Figure 6-2). The ridges along the West Access Channel and the Main Channel are the widest and highest and are no longer overtopped during normal flood stages. Spoil-elevated banks of Fausse Point Cut are somewhat narrower and lower, but still attain an elevation equal to or slightly above normal high-water level and also form a barrier to water exchange.